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(54) Title: NOISE REDUCTION

(57) Abstract

In a noise reduction filter comprising a filter (1) coupled to receive a plurality of input signal samples (Ø, ⊕) and furnishing noise-reduced signal samples, and a delay circuit (3A) which furnishes a plurality of delayed signal samples (X), the samples (Pn_1.. Pn_n) applied to the filter (1) are not-directly neighboring samples.

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Noise reduction.

The invention relates to a noise reduction filter, more particularly to a filter for image data noise reduction. The invention also relates to a noise reduction filtering method and to an image signal receiver comprising a noise reduction filter.

Noise reduction of image data is generally realized through averaging of likely correlated picture elements. The likelihood may be due to spatial or temporal proximity. The closer the proximity, the higher the likelihood that picture elements (pixels) have the same value if noise were not present. Both linear and non-linear filters have been used for noise reduction purposes, as well as the intermediate solution of adapting filter coefficients to local picture statistics.

The article "Extended-Order Statistic Filter and Evaluation of Noise Reduction Performance", Electronics and Communications in Japan, Part 3, Vol. 74, No. 5, 1991, pp. 1-11, discloses an extended-order statistic filter for image data noise reduction. The distinction between order statistic filters (OSF) and linear filters is that in an OSF, weighting coefficients are not related to the spatial or temporal distance with respect to the current sample, but to the order of the samples after ranking them on the basis of their signal value. In the extended-order statistic filter described in the article, the coefficients not only depend on the order of the signal values, but also on the order of differences between the signal values of neighboring samples and the signal value of the current sample (differential OSF), and further on the distance to the current sample. It was shown that this type of filter can combine the advantages of linear and non-linear filtering on gaussian noise and impulse noise, respectively. The transversal nature of these filters makes them rather expensive when applied to profit from the temporal correlation in image sequences.

JP-A-2/67,688 shows an image noise removing system in which, to prevent the generation of blur, filter characteristics are based on a relation between a central pixel and a weighted averaged pixel in the case of filtering a pixel positioned on the boundary of blocks. A weighted average of a central pixel and eight neighboring pixels surrounding the central pixel is determined. If the difference between the central pixel and

the weighted average is smaller than a threshold, the weighted average is supplied, whereas when the difference exceeds the threshold, the unfiltered central pixel is supplied.

DE-C-39.27.101 shows a noise reduction filter in which a delayed luminance signal and an undelayed luminance signal are only averaged if their difference is smaller than a given value. This corresponds to the noise removing system of JP-A-2/67,688 if instead of eight neighboring pixels surrounding the current pixel, only one neighboring pixel above the current pixel would be present. All disadvantages of the system of JP-A-2/67,688 are still present; in fact, the circuit of DE-C-39.27.101 can be considered as a primitive embodiment of the system of JP-A-2/67,688.

The article "Symmetrical recursive median filters; application to noise reduction and edge detection", by Ph. Bolon et al., Signal Processing V: theories and applications, pp. 813-816 shows a recursive median filter for noise reduction. A median filter is a species of the class of order statistic filters. The symmetrical filter described in the article, shows the disadvantage that for two-dimensionally filtering a current input pixel, information from the "future" (*i.e.* pixels below the current pixel when the pixels are scanned from top to bottom) is required, which is unattractive in view of a hardware realisation.

It is, *inter alia,* an object of the invention to provide a filter which provides a better reduction of low-frequency noise components. For this purpose, a first aspect of the invention provides a noise reduction filter as defined in claim 1. A second aspect of the invention provides an image signal receiver as defined in claim 12. A third aspect of the invention provides a noise reduction filtering method as defined in claim 13. Advantageous embodiments of the invention are defined in the subclaims.

In accordance with the present invention, instead of directly neighboring input pixels, pixels at some horizontal and/or vertical distance are used. It appeared that thereby, low-frequency noise components were reduced in addition to the high-frequency noise components which can also be reduced when directly neighboring input pixels are used. In one preferred embodiment, the recursive noise reduction filter receives 5 filtered pixels from the previous line having a distance of 4 pixels between two successive input pixels, 3 unfiltered pixels from the present line having a distance of 2 pixels between two successive input pixels. A ringing effect occurring at edges appeared to be reduced when the filtered input samples from the previous line were taken from positions shifted in the horizontal

direction line-alternatingly by +1, 0, -1, 0, +1, ... pixels. Many variations in the inter-pixel distance, the number of pixels used, and the magnitude of the line-alternating shift in the position of the filtered input pixels taken from the previous line are possible. In one embodiment, the inter-pixel distance depends on an edge-detection such that the inter-pixel distance decreases with an increasing difference between a current pixel and one of the neighboring pixels (e.g. the neighboring pixel having the largest distance to the current pixel). The inter-pixel distance may vary separately for left and right neighboring pixels.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

In the drawing:

Figs. 1A and 1B show block diagrams of embodiments of a noise reduction filter in accordance with the present invention;

Figs. 2A-2D show several configurations of neighboring pixels;

Fig. 3 shows an embodiment of a transversal noise reduction filter in accordance with the present invention;

Fig. 4 shows a switchable two-pixel delay circuit for use in the noise reduction filter of Fig. 3; and

Fig. 5 shows a block diagram of a preferred difference-dependent weighted average filter for use in the noise reduction filters of Fig. 1A, 1B and 3.

The embodiments of the invention shown in Figs. 1A, 1B concern non-linear recursive spatial or spatio-temporal filters. Other embodiments relate to transversal noise-reduction filters, while the invention is not limited to non-linear filters. Experiments indicate that the filters are attractive for use in future television receivers, as their performance is certainly superior to that of the presently used motion-adaptive temporal recursive filters, while their complexity is practically equivalent. In a preferred embodiment, for every pixel position $\underline{p} = (x, y, t)^T$, with T indicating transposition, and input luminance signal $F(\underline{p})$, the proposed filter output $F_F(\underline{p})$ will be defined as:

$$F_F(\underline{p}) = G(\underline{p}) \cdot \left[F(\underline{p}) + \gamma \cdot \sum_{\underline{n} \in N_1} \alpha(\underline{p}, \underline{n}) \cdot F(\underline{p} + \underline{n}) + \delta \cdot \sum_{\underline{n} \in N_2} \beta(\underline{p}, \underline{n}) \cdot F_F(\underline{p} + \underline{n}) \right] \quad (1)$$

where N_1 and N_2 are sets of vectors defining one, two, or three-dimensional neighborhoods. The recursivity of the filter results from the third term of equation (1) where the constant δ controls the amount of recursivity. Further, in accordance with the present embodiment of the invention and in contradistinction to an OSF or a differential OSF, filter weighting coefficients $\alpha(p, \underline{n})$ and $\beta(\underline{p}, \underline{n})$ are related to the absolute difference between the weighted pixel and the current input pixel:

$$\begin{aligned} \alpha(\underline{p}, \underline{n}) &= f_1(\,|\,F(\underline{p}) - F(\underline{p} + \underline{n})\,|\,) \\ \beta(\underline{p}, \underline{n}) &= f_2(\,|\,F(\underline{p}) - F_F(\underline{p} + \underline{n})\,|\,) \end{aligned} \quad (2)$$

with f_1 and f_2 monotonously decreasing functions. In equation (1), G is a gain or normalization factor:

$$\frac{1}{G(\underline{p})} = 1 + \gamma \cdot \sum_{\underline{n} \in N_1} \alpha(\underline{p}, \underline{n}) + \delta \cdot \sum_{\underline{n} \in N_2} \beta(\underline{p}, \underline{n}) \quad (3)$$

An attractive implementation results if the filter weighting coefficients are selected according to:

$$\alpha(\underline{p}, \underline{n}) = \begin{cases} 1, & (|\,F(\underline{p} + \underline{n}) - F(\underline{p})\,| < Th_1) \\ W, & (Th_1 \leq |\,F(\underline{p} + n) - F(\underline{p})\,| < Th_2) \\ 0, & (|\,F(\underline{p} + \underline{n}) - F(\underline{p})\,| \geq Th_2) \end{cases} \quad (4)$$

and:

$$\beta(\underline{p}, \underline{n}) = \begin{cases} 1, & (|\,F_F(\underline{p} + \underline{n}) - F(\underline{p})\,| < Th_1) \\ W, & (Th_1 \leq |\,F_F(\underline{p} + n) - F(\underline{p})\,| < Th_2) \\ 0, & (|\,F_F(\underline{p} + \underline{n}) - F(\underline{p})\,| \geq Th_2) \end{cases} \quad (5)$$

respectively.

Allowing only spatial recursion (only line memories, no field memories), good results were obtained using the following neighborhoods:

$$N_1 = \left\{ \begin{bmatrix} 2 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} -2 \\ 0 \\ 0 \end{bmatrix} \right\} \tag{6}$$

and:

$$N_2 = \left\{ \begin{bmatrix} 0 \\ -2 \\ 0 \end{bmatrix}, \begin{bmatrix} 4 \\ -2 \\ 0 \end{bmatrix}, \begin{bmatrix} -4 \\ -2 \\ 0 \end{bmatrix}, \begin{bmatrix} 8 \\ -2 \\ 0 \end{bmatrix}, \begin{bmatrix} -8 \\ -2 \\ 0 \end{bmatrix} \right\} \tag{7}$$

while selecting $W = 0.25$, $Th_2 = 4.Th_1$, and $\gamma = \delta = 1$, where Th_1 was adapted to the noise level. As can be seen from equations (6) and (7), the neighborhoods are selected such that pipe-lining of the algorithm implemented in a very large scale integration (VLSI) is simple.

When allowing for field memories in the design, a three-dimensional noise reduction filter can be realized, for which experimentally good results could be shown, applying the following neighborhoods:

$$N_1 = \left\{ \begin{bmatrix} 2 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} -2 \\ 0 \\ 0 \end{bmatrix} \right\} \tag{8}$$

and:

$$N_2 = \left\{ \begin{bmatrix} 0 + D_x \\ 1 + D_y \\ -T \end{bmatrix}, \begin{bmatrix} 0 + D_x \\ -1 + D_y \\ -T \end{bmatrix}, \begin{bmatrix} 4 + D_x \\ 1 + D_y \\ -T \end{bmatrix}, \begin{bmatrix} 4 + D_x \\ -1 + D_y \\ -T \end{bmatrix}, \begin{bmatrix} -4 + D_x \\ 1 + D_y \\ -T \end{bmatrix}, \begin{bmatrix} -4 + D_x \\ -1 + D_y \\ -T \end{bmatrix} \right\} \tag{9}$$

where $\underline{D}(\underline{x}, t) = (D_x, D_y)^T$ is the displacement vector describing the motion between field at time t and the previous field at time t-T, while selecting $W = 0.25$, $Th_2 = 4.Th_1$, and $\gamma = \delta = 1$, where Th_1 was adapted to the noise level as will be discussed below. In equation (9), T is the field period of the video signal, which equals 20 ms in a 50 Hz environment. Obviously, if no motion vectors are available, $\underline{D}(\underline{x}, t)$ can be taken $\underline{0}$. Again, as can be seen from the equations (9) and (10), the neighborhoods are selected taking implementation aspects, pipe-lining of the algorithm, into account. To obtain both spatial and temporal recursion, the set N_2 may be the union of the sets given in the equations (7) and (9).

In the noise reduction filter embodiments of Figs. 1A and 1B, the input to the difference-dependent weighted average calculation circuit 1A, 1B includes the current

sample ⊕ and several neighboring samples O and X, whereby part of the neighboring samples O and X are previously filtered samples X. In an image processing system, the delay of the delay circuit 3A, 3B in the feedback loop may be a line period (Fig. 1B), a field period or a picture period (Fig. 1A), plus or minus some pixel delays. When the delay is a field or picture period, the feedback loop preferably includes a motion compensation circuit to obtain a better matching of the pixels on which the recursive noise reduction filtering is based. Fig. 1A shows an embodiment of an interfield noise reduction filter in which the delay of the delay circuit 3A is a field or a picture delay, so that the neighboring fed-back pixels X may originate from both above and below the line comprising the current pixel ⊕; the left and right adjacent pixels O are from the same line and field as the current pixel ⊕. Fig. 1B shows an embodiment of an intrafield noise reduction filter in which the delay of the delay circuit 3B is a line delay, so that the neighboring fed-back pixels X originate from the line above the line comprising the current pixel ⊕; the left and right adjacent pixels O are from the same line as the current pixel ⊕.

In accordance with the present invention, instead of directly neighboring input pixels, pixels at some horizontal and/or vertical distance are used. It appeared that thereby, low-frequency noise components were reduced in addition to the high-frequency noise components which can also be reduced when directly neighboring input pixels are used. In one preferred embodiment, the recursive noise reduction filter receives 5 filtered pixels from the previous line having a distance of 4 pixels between two successive input pixels, 3 unfiltered pixels from the present line having a distance of 2 pixels between two successive input pixels. A ringing effect occurring at edges appeared to be reduced when the filtered input samples from the previous line (neighborhood N_2) were taken from positions shifted in the horizontal direction line-alternatingly by +1, 0, -1, 0, +1, ... pixels. Many variations in the inter-pixel distance, the number of pixels used, and the magnitude of the line-alternating shift in the position of the filtered input pixels taken from the previous line are possible. In one embodiment, the inter-pixel distance depends on an edge-detection such that the inter-pixel distance decreases with an increasing difference between a current pixel and one of the neighboring pixels (e.g. the neighboring pixel having the largest distance to the current pixel). The inter-pixel distance may vary separately for left and right neighboring pixels. A simple alternative for an edge-dependent switching of the filter is to give the pixel directly above the current pixel a weighting coefficient which is larger, for example, four times larger, than the weight it would have received in view of other considerations.

Figs. 2A-2D show several configurations of neighboring pixels. Fig. 2A shows the neighborhoods of formulae 6 and 7. Figs. 2A-2D show the line-alternating shift by +/- 1 pixel in the horizontal direction.

Fig. 3 shows an embodiment of a transversal noise reduction filter in accordance with the present invention. The input signal is applied to a tapped delay line 3C comprising a delay circuit H providing about one line delay, pixel delay circuits P and switchable two-pixel delay circuits 2P. The switchable two-pixel delay circuits 2P have a control input CI; if a control signal is applied to these control inputs CI, the delay period is shortened to a single pixel period. This can easily be achieved if the switchable two-pixel delay circuits 2P comprise a series connection of two pixel delay circuits P, and a switch to select the output of the first or the second pixel delay circuit P under control of the control signal applied to the control input CI as shown in Fig. 4. Switches S1-S5 select taps of the delay line 3C in a line-alternating manner to provide the sequence of pixel neighborhoods shown in Figs. 2A-2D. Outputs of the switches S1-S5 are applied to an averaging circuit 1C for providing 5 pixels X of the previous line thereto. The input of the noise reduction filter is also applied to a cascade connection of two switchable two-pixel delay circuits 2P, so as to provide a delay line having three taps for providing three pixels O of the current line. The input of the noise reduction filter is further applied to an edge detector 41 for generating the control input signal CI for the two pixel delay circuits 2P.

An attractive implementation of the difference-dependent weighted average calculating circuit is given in Fig. 5. The differences of all pixels in the filter window N1 plus N2 (in Fig. 5 indicated as Pn_1 .. Pn_n) with respect to the current input sample Pc, are calculated by subtracters 5 and absolute value determining circuits 7, and compared with a threshold Th_1 by comparators 9. The pixels for which the difference with the current sample is below the threshold Th_1, are averaged and the result is applied to the output of the noise reduction filter which is also the input of the delay circuit.

This action is carried out by multiplexers 11 controlled by the comparators 9 to furnish a weighting coefficient 0 when the difference is above the threshold Th_1 and to furnish a weighting coefficient α when the difference is below the threshold Th_1. Multipliers 13 multiply the neighboring pixels Pn with their respective weighting coefficients. The circuit of Fig. 5 is somewhat simplified with regard to equation (4): those differences between the neighboring pixel values Pn and the current pixel value Pc which are smaller than the threshold Th_1 result in a coefficient α for the corresponding neighboring pixel value

Pn, while the differences exceeding the threshold value Th_1 result in a coefficient 0 for the corresponding neighboring pixel value Pn. The current sample Pc is added to the weighted neighboring pixels Pn by adders 15, whose output signals are summed by an adder 17. The output of the adder 17 is multiplied by a gain coefficient to yield the output signal of the difference-dependent weighted average filter. When α equals 1, a simple average is used; when α differs from 1, a weighted average is used.

Rather than applying binary valued coefficients only, three or four different coefficient values (alpha 1, 2....n) can be applied, where the coefficients with the smallest value are assigned using the highest threshold (Th_1, Th_2, ...Th_n). Further as indicated in equation (2), the weights for previously filtered pixels can be selected different (β rather than α).

As mentioned hereinbefore, the threshold Th_1 (and therefore also Th_2, which has a fixed relation to Th_1) is preferably adapted to the noise level. A global adaptation (*i.e.* an adaptation for a whole picture) can be thought of and indeed proved useful. Hereinafter, a somewhat more sophisticated option adapting to local image characteristics is described. To this end, the image is divided into non-overlapping blocks $B(\underline{X})$, where $\underline{X} = (X, Y)^T$ is the center of the block. To each block a value of Th_1 is assigned, the calculation of which is based upon the Th_1 value in the previous field (temporal recursive adaptation process):

$$Th_1(\underline{X}, t) = Th_1(\underline{X}, t-T) - \Delta(\underline{X}, t) \tag{10}$$

with:

$$\Delta(\underline{X}, t) = C_1 \cdot \left(\sum_{\underline{x} \in B(\underline{X})} | F_F(\underline{X} + \underline{x}, t-T) - F(\underline{X} + \underline{x}, t-T) | - MinMad(t) \right) \tag{11}$$

where *MinMad* is an estimated value of the noise level in the field, and C_1 is a constant. A possible simplification is to use a sign function according to:

$$\Delta(\underline{X}, t) = C_1 . \mathrm{SIGN}\left(\sum_{\underline{x} \in B(\underline{X})} | F_F(\underline{X} + \underline{x}, t-T) - F(\underline{X} + \underline{x}, t-T) | - MinMad(t) \right) \tag{12}$$

where SIGN*(a)* is defined according to:

$$\mathrm{SIGN}(a) = \begin{cases} -1, & (a < 0) \\ +1, & (a \geq 0) \end{cases} \tag{13}$$

Experiments showed that *MinMad(t)* is preferably equal to the minimum in a field at time t of the motion-compensated summed absolute difference over a block of two successive fields:

$$MinMad(t) = \underset{\forall \underline{X} \in Field}{Min} \sum_{\underline{x} \in B(\underline{X})} | F(\underline{x}, t) - F(\underline{x} - \underline{D}(\underline{X}, t), t - T) | \qquad (14)$$

where $\underline{D}(\underline{X}, t)$ is the displacement vector found with a motion estimator for the block $B(\underline{X})$ at time t. The philosophy behind this choice is that *MinMad(t)* thus reflects the noise in the picture assuming that the estimator at least at one block of the image is converged completely.

In an attractive implementation, the motion estimator and the noise reduction circuit would share the picture memories, which is possible because the sum in equation (14) corresponds to the match error of the motion estimator. In this situation, however, the measured *MinMad(t)* corresponds to the reduced noise level, which is preferably corrected for the amount of filtering applied. Experimentally, it was verified that the following correction, the result of which is called *ModMad(t)*, yields satisfactory results:

$$ModMad(t) = ModMad(t - T) + Mod(t) \qquad (15)$$

where *Mod(t)* is found according to:

$$Mod(t) = C_2 \cdot \left(\frac{MinMad(t)}{C_3 \cdot \sum_{\underline{x} \in B(\underline{X})} G(\underline{x}, t)} - ModMad(t - T) \right) \qquad (16)$$

where $B(\underline{X})$ is the block where *MinMad(t)* was found, while C_2 and C_3 again are experimentally optimized constants. The first time *ModMad(t)* is calculated, *Modmad(t-T)* is assumed to be zero.

Rather than adapting Th_1 per block in the picture, or additional to it, local adaptation of γ and δ in equation (1) can be considered.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. Whenever

a first item is said to depend on a second item, it should be borne in mind that it is not excluded that the first item also depends on a third item.

As an alternative to the use of the recursive noise reduction filter of Fig. 5 using all neighboring samples which differ by less than a (noise adapted) threshold from the current pixel value, it is possible to average the n least differing (compared to the current pixel) pixel values, in which case n depends on the noise level.

In a television signal receiver having a luminance noise reduction filter and a chrominance noise reduction filter, filter coefficients of the chrominance noise reduction filter are preferably dependent on differences between neighboring luminance pixel values. This yields as an unexpected advantage that cross-color is reduced. This effect can be explained as follows. Suppose an *e.g.* horizontal high-frequency luminance pattern. The horizontal high-frequency luminance pattern will cause an undesired cross-color having vertical components. To avoid that the horizontal high-frequency information will be damaged by the noise reduction filtering, the noise reduction filtering will be predominantly vertically oriented. Such a vertically oriented noise reduction filtering will not only filter the vertical noise components, but also the vertical cross-color components and thus reduce the cross-color.

Thus, in accordance with the present invention, a family of noise-reduction filters is proposed, which experimentally shows a particularly good suitability for noise reduction application in image data processing. It concerns a class of spatial and spatio-temporal filters, for which options are given to adapt to noise level and local image characteristics. In embodiments of the noise reduction filter in accordance with the present invention, weights are related to the absolute difference between samples. It is shown that particularly multi-dimensional recursive variants of this nonlinear filter family are attractive for noise reduction of images. The recursivity can be designed to facilitate implementation at high processing speed, *i.e.* the definition of the noise reduction filter allows for pipe-lining. In case of temporal recursion, motion-compensation turns out to increase the performance. An attractive implementation of the weight calculation circuit is provided, and methods are indicated to adapt the filter to the noise level in the picture and to the local characteristics of the picture.

Claims:

1. A noise reduction filter comprising:
delay means (3) for furnishing delayed signal samples (X); and
a filter (1) coupled to receive input signal samples (O,⊕) and said delayed signal samples (X) to furnish noise-reduced signal samples, wherein
said samples ($Pn_1..Pn_n$) applied to said filter (1) are not-directly neighboring samples.

2. A noise reduction filter as claimed in claim 1, wherein a distance between said not-directly neighboring samples depends on an edge-detection such that said distance decreases with an increasing difference between a current sample (⊕,Pc) and one of said not-directly neighboring samples.

3. A noise reduction filter as claimed in claim 1, wherein said delayed samples (X) from a previous line are taken from positions line-alternatingly shifted in the horizontal direction.

4. A noise reduction filter as claimed in claim 1, wherein said input samples (O,⊕) are all on a first horizontal line of an image signal, while said delayed signal samples (X) are all on one or more lines other than said first horizontal line.

5. A noise reduction filter as claimed in claim 1, wherein said filter (1) is a weighted average filter, and weighting coefficients assigned to samples ($Pn_1..Pn_n$) of said input signal (O) and said delayed signal (X) depend on respective differences between a current sample (⊕,Pc) of said input signal on the one hand and said samples ($Pn_1..Pn_n$) of said input signal (O) and said delayed signal (X) on the other hand.

6. A noise reduction filter as claimed in claim 5, wherein a first weighting coefficient is assigned to samples ($Pn_1..Pn_n$) of said input signal (O) and said delayed signal (X) differing by less than a threshold value from said current sample (⊕,Pc) of said input signal, while weighting coefficients differing from said first weighting coefficient are

assigned to samples ($Pn_1..Pn_n$) of said input signal (O) and said delayed signal (X) differing by more than said threshold value from said current sample (⊕,Pc) of said input signal.

7. A noise reduction filter as claimed in claim 6, wherein a second weighting coefficient smaller than said first weighting coefficient is assigned to those samples ($Pn_1..Pn_n$) which differ from the current sample (⊕,Pc) by more than said first-mentioned threshold value and by less than a second threshold value, which second threshold value is larger than said first threshold value.

8. A noise reduction filter as claimed in claim 6, wherein said threshold value depends on the noise level.

9. A noise reduction filter as claimed in claim 6, wherein said threshold value depends on a minimum in a field of a motion-compensated difference between two successive fields.

10. A noise reduction filter as claimed in claim 5, wherein weighting coefficients for a chrominance signal noise reduction filtering depend on differences between neighboring luminance sample values.

11. A noise reduction filter as claimed in claim 1, wherein said delay means (3) comprise motion vector compensation means.

12. An image signal receiver comprising a signal input for receiving an image signal, a signal processor for processing said image signal, and a display unit for displaying the processed image signal, wherein said signal processor comprises a noise reduction filter as claimed in any of the preceding claims.

13. A noise reduction filtering method comprising the steps of:

furnishing (3) delayed signal samples (X); and

filtering (1) input signal samples (O,⊕) and said delayed signal samples (X) to furnish noise-reduced signal samples, wherein

said samples ($Pn_1..Pn_n$) applied to said filter (1) are not-directly neighboring samples.

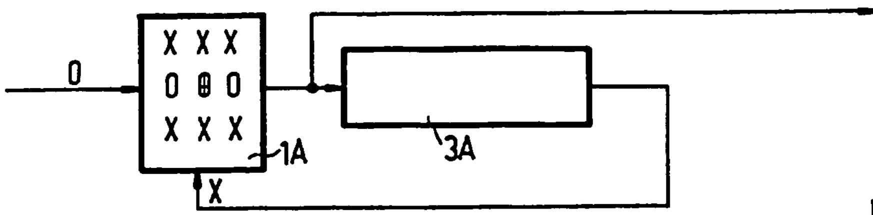

FIG.1A

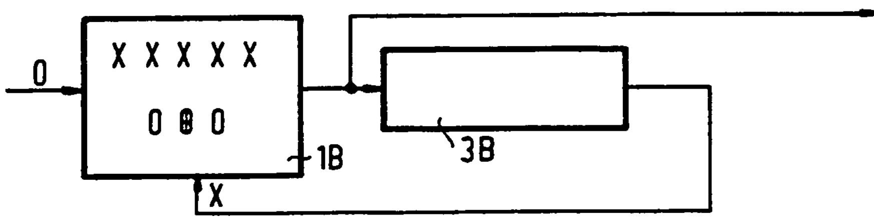

FIG.1B

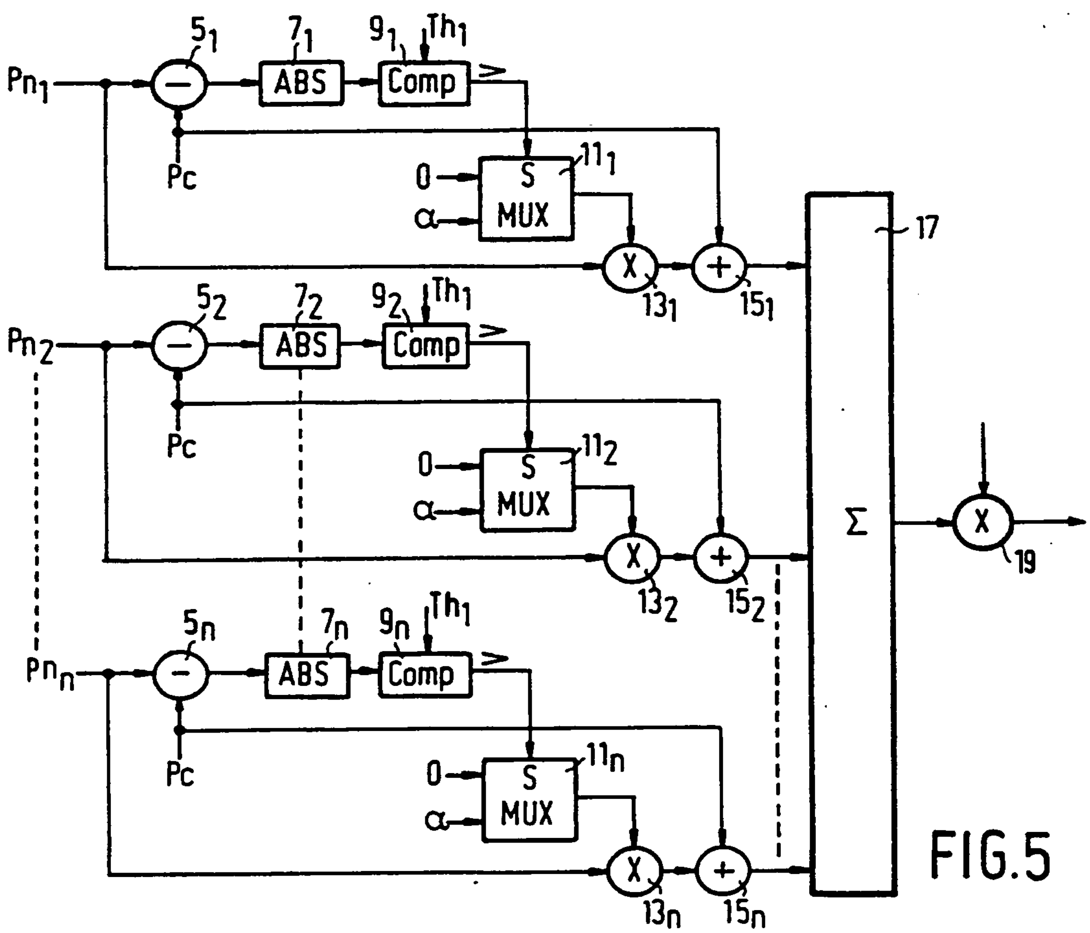

FIG.5

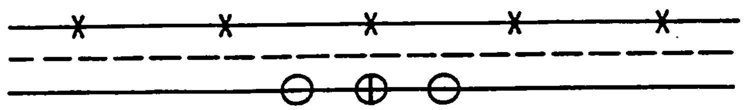
FIG.2A

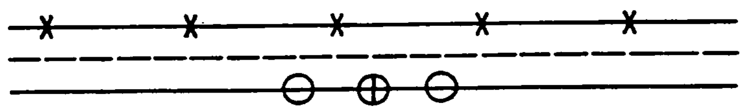
FIG.2B

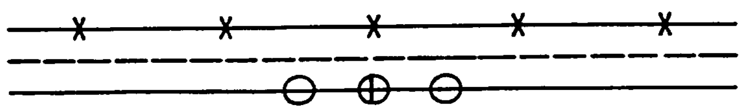
FIG.2C

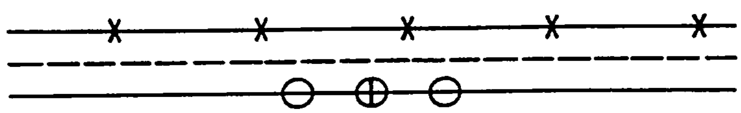
FIG.2D

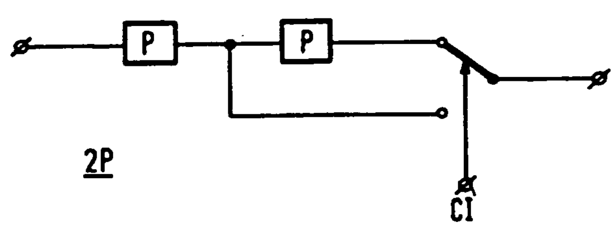

FIG.4

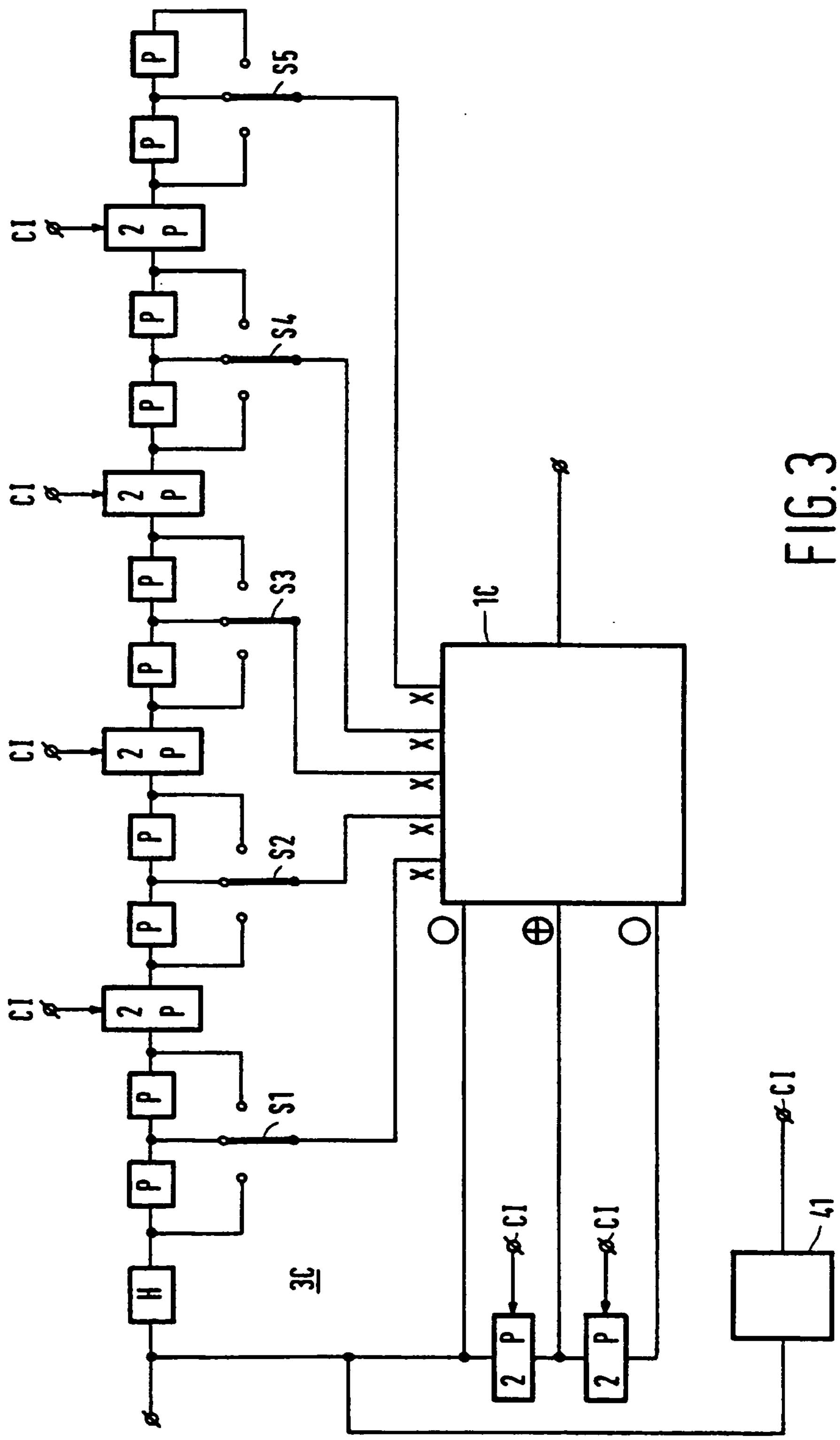

FIG. 3